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Hot Mix Asphalt (HMA) using up to 15% Reclaimed Asphalt Pavement (RAP)

1. SCOPE

1.1 Reclaimed asphalt pavement (RAP) may be combined with virgin aggregate and new asphalt binder at a central mixing plant to produce hot mix asphalt (HMA).

1.2 This lab procedure is applicable to all HMA mixtures containing up to 15% RAP aggregate in the aggregate blend.

1.3 RAP is not allowed in rubberized asphalt concrete (RAC) and open-graded mixtures.

1.4 Physical properties of the asphalt extracted from RAP and RAP aggregate will not be tested.

2. SUMMARY OF METHOD

2.1 Obtain representative samples of the RAP (See Section 3).

2.2 Evaluate the RAP (See Section 4). Determine:

a) Amount of asphalt binder
b) Aggregate gradation
c) Theoretical maximum specific gravity using CT 309 (Rice).

2.3 Prepare the mix design (See Section 5):

a) Determine the combined gradation of the HMA mixture based on proposed proportions of RAP and virgin aggregate to be used.
b) Determine the approximate bitumen ratio (ABR) of the combined aggregate.
c) Calculate the amount of new asphalt binder in the HMA mixture.
d) Calculate batch weights for each ingredient in the mixture.
e) Prepare and test specimens using Hveem apparatus.
f) Determine the optimum bitumen content (OBC).

2.4 Conduct testing during production (See Section 6).

3. RAP SAMPLING

3.1 For the mix design, a minimum of 3 separate representative samples of RAP (minimum 40 lbs. each) shall be obtained in accordance with the applicable sections of CT 125, Part 1, except processed RAP may be sampled from stockpiles.

3.2 During production, representative samples of RAP shall be obtained in accordance with the applicable sections of CT 125, Part 1, and the following:

- Batch Plant – Samples shall be taken from the RAP system as it is discharged into the weigh hopper (CT 125, Part 1, Section 1).

- Continuous Mixing Plant – Samples shall be taken from the RAP system as it enters the pugmill or drier-drum mixer (CT 125, Part 1, Section 2).

4. RAP EVALUATION

4.1 Prepare each RAP sample separately for evaluation.

4.2 Particles of RAP shall be separated by hand so that the particles of the fine aggregate portion are no larger than ¼-inch. Care shall be taken to avoid fracturing the aggregate.

4.3 Samples shall be prepared in accordance with CT 201. Split or quarter each sample into representative portions for ASTM D 2172, CT 382, and CT 309 testing. After the required test samples have been prepared, combine the remaining RAP material for subsequent splitting into representative mix design test samples.

4.4 Determine the asphalt binder content of each RAP sample using ASTM D 2172, Method B (3 minimum). Calculate and report the individual and average asphalt binder content. Perform a sieve analysis on each sample of recovered aggregate in accordance with CT 202, Appendix A (3 minimum). Calculate and report the individual and average gradation.

4.5 Burn asphalt from each RAP sample in accordance with CT 382 for aggregate gradation (3 minimum). Calculate and report the individual and average asphalt binder content (for information only). Perform a sieve analysis on each sample of recovered aggregate in accordance with CT 202, Appendix A (3 minimum). Calculate and report the individual and average gradations.

4.6 Determine a correlation factor to be used for RAP gradation testing during production. The correlation factor for each sieve shall be determined by taking the average gradation of the ASTM D 2172 samples minus the average gradation of the CT 382 samples.

4.7 If voids in mineral aggregate (VMA) is specified, determine the theoretical maximum specific gravity (Rice) of each RAP sample in accordance with CT 309, Section J (3 minimum). Calculate and report the individual and average values.

The above procedures are summarized in Table 1:

Table 1 – RAP Evaluation

Tests	Sample			Description
	1	2	3	
ASTM D 2172, Method B	X	X	X	Report individual and average asphalt contents to 0.1%
CT 202, Appendix A				Report individual and average gradation results for each sieve.
CT 382 for	X	X	X	Report individual and average asphalt contents to 0.1% (for information only).
CT 202, Appendix A				Report individual and average gradation results for each sieve.
CT 309, Section J	X	X	X	Report individual and average results.
Determine Aggregate Gradation Correlation Factor	X			Average gradation of ASTM D 2172 minus average gradation of CT 382

5. MIX DESIGN

5.1 Determine the RAP percentage that will be used in the mix design (maximum 15% RAP aggregate in the aggregate blend).

5.2 Determine the combined gradation of the HMA mixture based on proposed proportions of RAP and virgin aggregate to be used in accordance with CT 202.

5.3 Determine "K" values of the virgin aggregate portion using CT 303.

5.4 Determine the ABR of the combined aggregate gradation as follows:

$$ABR = \frac{4R + 7S + 12F}{100}$$

Where:

ABR = Approximate Bitumen Ratio (<u>total</u> asphalt content).
R = % retained on the No. 8 sieve.
S = % passing the No. 8 sieve and retained on the No. 200 sieve.
F = % passing the No. 200 sieve.

5.5 Calculate batch weights for each ingredient in the mixture using the provided batching sheet.

(Note: When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP.)

5.6 The RAP shall be oven dried to a constant mass in accordance with CT 226, except the temperature shall not exceed 100°F.

5.7 Prepare and test specimens (virgin aggregate, RAP, and new asphalt binder) in accordance with CT 304 except as follows:

a) If treating aggregate with lime (anti-strip) is specified, only the virgin aggregate shall be treated. Treating the RAP with lime is not required.

b) Virgin aggregate shall be heated to 20°F above mixing temperature and RAP shall be heated to 230°F for a maximum of 2 hours. RAP shall not be reheated.

c) Add the proper amount of virgin aggregate to the mixing bowl and then add the proper amount of RAP. Dry mix for a minimum of 10 seconds. Add the proper amount of asphalt binder and proceed with wet mixing.

d) Use CT 309 to measure theoretical maximum specific gravity (Rice) in accordance with LP-1, in lieu of calculating maximum specific gravity in CT 367.

e) Lab Procedure 2 (LP-2) shall be used to calculate VMA.

f) Otherwise, normal mix design procedures shall be followed.

6. TESTING DURING PRODUCTION TO VERIFY JOB MIX FORMULA (JMF)

6.1 During production, sample and test as normal except as follows:

a) Asphalt Content - When developing a correction factor for asphalt content (CT 379 or 382), include the proposed portion of RAP. A new correction factor will not be required unless the RAP proportion changes by more than 5% from the JMF.

Samples for determining asphalt content shall be taken in accordance with CT 125, Part 7.

b) Aggregate Gradation - When determining the combined gradation, burn off the RAP sample in accordance with CT 382. Report the asphalt content of the RAP sample to 0.1% (for information purposes only). Perform a sieve

analysis on recovered aggregate in accordance with CT 202, Appendix A. Add the correlation factor established in Section 4.6. Report the actual gradation, the correlation factor, and the corrected gradation for each sieve size. Mathematically combine the virgin and corrected RAP aggregate gradations at the correct proportions to obtain the combined gradation.

7. EXAMPLE

(See spreadsheet)

7. EXAMPLE

7.1 RAP EVALUATION

Determine the asphalt content and gradation of the RAP aggregate for the samples provided:

7.1.1 Given:

Test	CT 125, Part 1	ASTM D2172, Method B	*CT 382*	CT 309
RAP Sample	Weight (lbs.)	Asphalt Content[1] (%)	*Asphalt Content[2] (%)*	Theo. Max Specific Gravity of RAP (G_{mmr})
I	42	5.7	*5.8*	2.535
II	44	5.5	*5.5*	2.521
III	41	5.8	*5.9*	2.542
AVERAGE	42.3	5.7	*5.7*	2.533

[1] % by weight aggregate; [2] For information only

CT 202 RAP Gradation (aggregate recovered from ASTM D 2172 & CT 382 tests):

Sieve Size	Sample I		Sample II		Sample III	
	ASTM D2172	CT 382	ASTM D2172	CT 382	ASTM D2172	CT 382
1 1/2"	100.0	100.0	100.0	100.0	100.0	100.0
1"	100.0	100.0	100.0	100.0	100.0	100.0
3/4"	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	82.3	81.5	81.1	81.9	84.3	83.9
3/8"	78.2	78.7	77.5	76.8	75.1	74.3
No. 4	62.4	63.3	65.2	63.8	59.4	61.4
No. 8	51.2	50.5	50.3	49.7	44.6	45.1
No. 16	38.5	39.0	35.6	34.7	28.7	28.2
No. 30	27.6	27.2	21.8	22.2	19.9	20.6
No. 50	17.7	17.4	13.2	13.5	12.8	10.5
No. 100	11.1	11.3	9.4	8.9	13.2	12.7
No. 200	4.8	4.2	5.1	4.7	5.3	3.9

Calculate: **RAP Aggregate Gradation Correlation Factor**

For each sieve:

RAP Aggregate Gradation Correlation Factor = (Average ASTM D 2172 gradation) - (Average CT 382 gradation)

Sieve Size	Average RAP Gradation		Correlation Factor
	ASTM D2172	CT 382	
1 1/2"	100.0	100.0	0.0
1"	100.0	100.0	0.0
3/4"	100.0	100.0	0.0
1/2"	82.6	82.4	0.2
3/8"	76.9	76.6	0.3
No. 4	62.3	62.8	-0.5
No. 8	48.7	48.4	0.3
No. 16	34.3	34.0	0.3
No. 30	23.1	23.3	-0.2
No. 50	14.6	13.8	0.8
No. 100	11.2	11.0	0.3
No. 200	5.1	4.3	0.8

7.2 MIX DESIGN

Determine a mix design incorporating 10% RAP aggregate in the aggregate blend (15% maximum)

7.2.1 Given: **VIRGIN AGGREGATE K FACTORS** (See CT 303)

Relative particle roughness and surface capacity

K_c	K_f
1.0	1.6

COMBINED AGGREGATE GRADATION (See Table 2 of the example work sheet in Section 7.2.3)

Combined Gradation Summary

AGGREGATE:	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand		Blend[2]	Spec Limits
% Blend w/ RAP	10.0		5.0		28.0		26.0		21.0		10.0		0.0		100.0	
% Blend w/o RAP	0.0		5.6		31.1		28.9		23.3		11.1		0.0		100.0	
Sieve Size	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Total Blend (w/ RAP)	
1 1/2"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	
1"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
3/4"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
1/2"	100.0	10.0	93.3	4.7	93.9	26.3	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	98.0	79-99
3/8"	100.0	10.0	25.3	1.3	29.9	8.4	96.3	25.0	100.0	21.0	100.0	10.0	0.0	0.0	75.7	68-88
No. 4	83.0	8.3	2.0	0.1	4.3	1.2	32.0	8.3	99.2	20.8	97.5	9.8	0.0	0.0	48.5	48-68
No. 8	66.0	6.6	1.0	0.1	3.0	0.8	8.0	2.1	88.7	18.6	80.6	8.1	0.0	0.0	36.3	33-53
No. 16	52.0	5.2	1.0	0.1	3.0	0.8	4.0	1.0	66.1	13.9	62.6	6.3	0.0	0.0	27.3	20-40
No. 30	39.0	3.9	1.0	0.1	3.0	0.8	3.0	0.8	48.6	10.2	43.3	4.3	0.0	0.0	20.1	14-30
No. 50	26.0	2.6	1.0	0.1	2.0	0.6	2.0	0.5	33.0	6.9	21.8	2.2	0.0	0.0	12.8	9-21
No. 100	16.0	1.6	1.0	0.1	2.0	0.6	1.0	0.3	20.0	4.2	7.2	0.7	0.0	0.0	7.4	6-16
No. 200	10.6	1.1	1.0	0.1	1.0	0.3	1.0	0.3	13.6	2.9	3.3	0.3	0.0	0.0	4.8	3-6

[2] Must = 100%

Calculate: **Approximate Bitumen Ratio (ABR) and the percentage of coarse, fine, and RAP aggregate in the aggregate blend**

First, check the K factors of the virgin aggregate:

Per Section 39-2.02 of the Standard Specifications, K_c and K_f cannot exceed 1.7:

$K_c = 1.0 < 1.7$ => **OK** $K_f = 1.6 < 1.7$ => **OK**

Now, determine ABR of combined aggregate:

$$ABR = \frac{4R + 7S + 12F}{100}$$

Where:

R = (% retained No. 8)
S = (% passing No. 8 & retained No. 200)
F = (% passing No. 200)

R = (% retained No. 8) = 100% - (% passing No. 8)
= 100% - 36.3%
= **63.7%**

S = (% passing No. 8) - (% passing No. 200)
= 36.3% - 4.8%
= **31.5%**

F = (% passing No. 200)
= **4.8%**

Therefore:

$$ABR = \frac{4R + 7S + 12F}{100} = \frac{(4 \times 63.7) + (7 \times 31.5) + (12 \times 4.8)}{100} = 5.3\%$$

Now, determine the percentage of coarse, fine, and RAP aggregate in the aggregate blend:

Coarse aggregate (P_1) (retained No. 4 sieve)	= (100% - % total blend passing No. 4) - (RAP aggregate in blend -% RAP passing No. 4) = (100% - 48.5%) - (10% - 8.3%) P_1 = **49.8%**
Fine aggregate (P_2) (passing No. 4 sieve)	= (% total blend passing No. 4) - (% RAP passing No. 4) = (48.5% - 8.3%) P_2 = **40.2%**
RAP aggregate (P_3)	P_3 = **10.0%**

Check: $P_1 + P_2 + P_3 = 49.8\% + 40.2\% + 10.0\% = 100\%$

7.2 MIX DESIGN (Continued):

7.2.2 Given: **BATCH WEIGHT INPUTS**

(Note: given inputs are for one sample with asphalt content equal to ABR. When using the batching worksheet shown in Section 7.4 to develop a mix design, inputs for each sample must be entered separately.)

Table 3: Input for Bin Batch Weights (from Table 1 of the example work sheet in Section 7.2.3)[3]

Total Asphalt Content, %	5.3
Desired Sample Wt., g	1200.0
Weight of RAP, g	120.5
Weight of New Asphalt, g	53.9
Wt. of Virgin Aggregate, g	1025.6

[3] When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP. Therefore, the input data above must be entered separately for each total desired asphalt content to properly determine batch weights at each asphalt content.

Calculate: **BATCH WEIGHTS (See the example work sheet in Section 7.2.3)**

Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
		120.5		57.0		319.1		296.3		239.3		114.0		0.0
1" - 3/4"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/4" - 1/2"	0.0	**0.0**	6.7	**3.8**	6.1	**19.5**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
1/2" - 3/8"	0.0	**0.0**	68.0	**38.7**	64.0	**204.2**	3.7	**11.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/8" - No. 4	17.0	**20.5**	23.3	**13.3**	25.6	**81.7**	64.3	**190.5**	0.8	**1.9**	2.5	**2.8**	0.0	**0.0**
No. 4 - PAN	83.0	**100.0**	2.0	**1.1**	4.3	**13.7**	32.0	**94.8**	99.2	**237.4**	97.5	**111.1**	0.0	**0.0**
	100.0	***120.5***	100.0	***57.0***	100.0	***319.1***	100.0	***296.3***	100.0	***239.3***	100.0	***114.0***	0.0	***0.0***

Cumulative Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
1" - 3/4"	0.0	**0.0**	0.0	**120.5**	0.0	**177.4**	0.0	**496.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
3/4" - 1/2"	0.0	**0.0**	3.8	**124.3**	19.5	**196.9**	0.0	**496.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
1/2" - 3/8"	0.0	**0.0**	38.7	**163.0**	204.2	**401.1**	11.0	**507.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
3/8" - No. 4	20.5	**20.5**	13.3	**176.3**	81.7	**482.8**	190.5	**698.0**	1.9	**794.7**	2.8	**1035.0**	0.0	**1146.1**
No. 4 - PAN	100.0	**120.5**	1.1	**177.4**	13.7	**496.5**	94.8	**792.8**	237.4	**1032.1**	111.1	**1146.1**	0.0	**1146.1**
	120.5		57.0		319.1		296.3		239.3		114.0		0.0	

7.2 MIX DESIGN (Continued):

7.2.3 Given:

Component	Bulk Specific Gravity	Composition (%)	Source
Asphalt binder in RAP	1.02 (G_{br})	P_{br} = 5.7%	Section 7.1.1
Asphalt binder in mix	1.02 (G_b)	Use ABR=P_b= 5.3%	Section 7.2.1
Coarse aggregate (retained No. 4 sieve)	2.720 (G_1)	P_1 = 49.8%	
Fine aggregate (passing No. 4 sieve)	2.700 (G_2)	P_2 = 40.2%	
RAP	Calculate	P_3 = 10%	
Compacted Mixture	2.440 (G_{mb})	----	CT 308, Method A

Where: ABR = Approximate Bitumen Ratio for the combined aggregate gradation (from Section 7.2.1)

P_n = composition, % by dry weight of aggregate

G_{se} = effective specific gravity of RAP aggregate (assumed equal to bulk specific gravity)

Calculate: **VOIDS in MINERAL AGGREGATE (VMA) - See Lab Procedure 2**

First, calculate the effective specific gravity of the RAP aggregate:

From LP-2:

$$G_{se} = \frac{100}{\frac{100 + P_{br}}{G_{mmr}} - \frac{P_{br}}{G_{br}}}$$

Where:

G_{br} = specific gravity of asphalt binder in RAP = 1.02

G_{mmr} = maximum specific gravity of RAP mixture (CT 309)

P_{br} = asphalt binder content of RAP, % by weight of aggregate

} Given in 7.1.1

Sample I: $G_{se} = \frac{100}{\frac{100 + 5.7}{2.535} - \frac{5.7}{1.02}} =$ **2.769**

Sample II: $G_{se} = \frac{100}{\frac{100 + 5.5}{2.521} - \frac{5.5}{1.02}} =$ **2.743**

Sample III: $G_{se} = \frac{100}{\frac{100 + 5.8}{2.542} - \frac{5.8}{1.02}} =$ **2.783**

Average $G_{se} = \frac{2.769 + 2.743 + 2.783}{3} =$ **2.765**

Now, find the bulk specific gravity of the aggregate blend (G_{sb}):

$$G_{sb} = \frac{P_1 + P_2 + P_3}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \frac{P_3}{G_{se}}} = \frac{49.8 + 40.2 + 10.0}{\frac{49.8}{2.720} + \frac{40.2}{2.700} + \frac{10.0}{2.765}} = 2.716$$

Therefore:

$$VMA = 100 - \left[\frac{G_{mb}}{G_{sb}} \times \left(\frac{100}{100 + P_b}\right) \times 100\right] = 100 - \left[\frac{2.440}{2.716} \times \left(\frac{100}{100 + 5.3}\right) \times 100\right] = 14.7$$

7.2.3 Example Worksheet for Computing Laboratory Batch Weights for HMA Mixtures Containing RAP

Date: _____
Mix Type: _____

Prepared By: _____

[ ] - yellow cell denotes a required input.

% RAP Aggregate in Aggregate Blend (15% Maximum)	Asphalt Content of RAP (DWA)[1]
10	5.7

[1] DWA = Dry Weight of Aggregate

Table 1: Batch Weights for Virgin Aggregate, RAP, and New Asphalt Binder

Parameter	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Desired Total Asphalt Content of Mix, % (DWA)	4.3	4.8	5.3	5.8	6.3
Desired Hot Mix Sample Weight, g	1200	1200	1200	1200	1200
Desired Weight of Aggregate, g	1150.5	1145.0	1139.6	1134.2	1128.9
New Asphalt, % (DWA)	3.7	4.2	4.7	5.2	5.7
Weight of New Asphalt to be Added, g	42.9	48.4	53.9	59.3	64.7
RAP, % (DWA)	10.6	10.6	10.6	10.6	10.6
Weight of RAP to be Added, g	121.6	121.0	120.5	119.9	119.3
New Aggregate, %	90	90	90	90	90
Weight of Virgin Aggregate, g	1035.5	1030.5	1025.6	1020.8	1016.0
Check	1200.0	1200.0	1200.0	1200.0	1200.0

Table 2: Combined Gradation Summary

AGGREGATE:	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand		Blend[2]	Spec Limits
% of Blend w/ RAP:	10.0		5.0		28.0		26.0		21.0		10.0		0.0		100.0	
% of Blend w/o RAP:	0.0		5.6		31.1		28.9		23.3		11.1		0.0		100.0	
Sieve Size	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Total Blend (w/ RAP)	
1 1/2"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	
1"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
3/4"	100.0	10.0	100.0	5.0	100.0	28.0	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	100.0	100
1/2"	100.0	10.0	93.3	4.7	93.9	26.3	100.0	26.0	100.0	21.0	100.0	10.0	0.0	0.0	98.0	79-99
3/8"	100.0	10.0	25.3	1.3	29.9	8.4	96.3	25.0	100.0	21.0	100.0	10.0	0.0	0.0	75.7	68-88
No. 4	83.0	8.3	2.0	0.1	4.3	1.2	32.0	8.3	99.2	20.8	97.5	9.8	0.0	0.0	48.5	48-68
No. 8	66.0	6.6	1.0	0.1	3.0	0.8	8.0	2.1	88.7	18.6	80.6	8.1	0.0	0.0	36.3	33-53
No. 16	52.0	5.2	1.0	0.1	3.0	0.8	4.0	1.0	66.1	13.9	62.6	6.3	0.0	0.0	27.3	20-40
No. 30	39.0	3.9	1.0	0.1	3.0	0.8	3.0	0.8	48.6	10.2	43.3	4.3	0.0	0.0	20.1	14-30
No. 50	26.0	2.6	1.0	0.1	2.0	0.6	2.0	0.5	33.0	6.9	21.8	2.2	0.0	0.0	12.8	9-21
No. 100	16.0	1.6	1.0	0.1	2.0	0.6	1.0	0.3	20.0	4.2	7.2	0.7	0.0	0.0	7.4	6-16
No. 200	10.6	1.1	1.0	0.1	1.0	0.3	1.0	0.3	13.6	2.9	3.3	0.3	0.0	0.0	4.8	3-6

[2] Must = 100%

Table 3: Input for Bin Batch Weights (from Table 1)[3]

Total Asphalt Content, %	5.3
Desired Sample Wt., g	1200
Weight of RAP, g	120.5
Weight of New Asphalt, g	53.9
Wt. of Virgin Aggregate, g	1025.6

[3] When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP. Therefore, the input data above must be entered separately for each total desired asphalt content to properly determine batch weights at each asphalt content.

Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
		120.5		57.0		319.1		296.3		239.3		114.0		0.0
1" - 3/4"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/4" - 1/2"	0.0	**0.0**	6.7	**3.8**	6.1	**19.5**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
1/2" - 3/8"	0.0	**0.0**	68.0	**38.7**	64.0	**204.2**	3.7	**11.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/8" - No. 4	17.0	**20.5**	23.3	**13.3**	25.6	**81.7**	64.3	**190.5**	0.8	**1.9**	2.5	**2.8**	0.0	**0.0**
No. 4 - PAN	83.0	**100.0**	2.0	**1.1**	4.3	**13.7**	32.0	**94.8**	99.2	**237.4**	97.5	**111.1**	0.0	**0.0**
	100.0	***120.5***	100.0	***57.0***	100.0	***319.1***	100.0	***296.3***	100.0	***239.3***	100.0	***114.0***	0.0	***0.0***

Cumulative Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
1" - 3/4"	0.0	**0.0**	0.0	**120.5**	0.0	**177.4**	0.0	**496.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
3/4" - 1/2"	0.0	**0.0**	3.8	**124.3**	19.5	**196.9**	0.0	**496.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
1/2" - 3/8"	0.0	**0.0**	38.7	**163.0**	204.2	**401.1**	11.0	**507.5**	0.0	**792.8**	0.0	**1032.1**	0.0	**1146.1**
3/8" - No. 4	20.5	**20.5**	13.3	**176.3**	81.7	**482.8**	190.5	**698.0**	1.9	**794.7**	2.8	**1035.0**	0.0	**1146.1**
No. 4 - PAN	100.0	**120.5**	1.1	**177.4**	13.7	**496.5**	94.8	**792.8**	237.4	**1032.1**	111.1	**1146.1**	0.0	**1146.1**
	120.5		57.0		319.1		296.3		239.3		114.0		0.0	

- yellow cell denotes a required input.

7.3 PRODUCTION TESTING

7.3.1 Given: Production testing data for 1500 tons of paving:

CT 202 Actual Gradation (aggregate from CT 382):

Sieve Size	**RAP** (daily sample)	**Virgin Aggregate** (sample/ 500 ton)			**Spec Limits**
		Sample A	Sample B	Sample C	
1 1/2"	100.0	100.0	100.0	100.0	
1"	100.0	100.0	100.0	100.0	100
3/4"	100.0	100.0	100.0	100.0	100
1/2"	88.7	83.2	94.0	91.5	79-99
3/8"	73.1	76.3	69.2	75.7	68-88
No. 4	53.3	56.5	54.3	51.1	48-68
No. 8	42.4	44.1	48.7	43.2	33-53
No. 16	33.3	36.7	37.8	29.6	20-40
No. 30	24.6	21.1	22.9	26.3	14-30
No. 50	16.2	18.7	13.6	16.4	9-21
No. 100	10.8	14.4	12.1	15.3	6-16
No. 200	4.5	3.5	4.2	5.1	3-6

Calculate: **Corrected RAP Gradation (for each sieve); Combined Gradation**

Corrected RAP gradation = (Actual gradation) + (correlation factor)

Combined gradation = (% RAP in mix) x (Corrected RAP gradation) + (% Virgin Aggregate in mix) x (Sample gradation)

Sieve Size	**Correlation Factor** (from 7.1.1)	**RAP 10%**		**Virgin Aggregate 90%**			**Combined Gradation**			**Spec Limits**
		Actual Gradation	**Corrected Gradation**	Sample A	Sample B	Sample C	Sample A	Sample B	Sample C	
1 1/2"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	
1"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	100
3/4"	0.0	100.0	**100.0**	100.0	100.0	100.0	**100.0**	**100.0**	**100.0**	100
1/2"	0.2	88.7	**88.9**	83.2	94.0	91.5	**83.8**	**93.5**	**91.2**	79-99
3/8"	0.3	73.1	**73.4**	76.3	69.2	75.7	**76.0**	**69.6**	**75.5**	68-88
No. 4	-0.5	53.3	**52.8**	56.5	54.3	51.1	**56.1**	**54.2**	**51.3**	48-68
No. 8	0.3	42.4	**42.7**	44.1	48.7	43.2	**44.0**	**48.1**	**43.1**	33-53
No. 16	0.3	33.3	**33.6**	36.7	37.8	29.6	**36.4**	**37.4**	**30.0**	20-40
No. 30	-0.2	24.6	**24.4**	21.1	22.9	26.3	**21.4**	**23.0**	**26.1**	14-30
No. 50	0.8	16.2	**17.0**	18.7	13.6	16.4	**18.5**	**13.9**	**16.5**	9-21
No. 100	0.3	10.8	**11.1**	14.4	12.1	15.3	**14.1**	**12.0**	**14.9**	6-16
No. 200	0.8	4.5	**5.3**	3.5	4.2	5.1	**3.7**	**4.3**	**5.1**	3-6

7.4 Blank Worksheet for Computing Laboratory Batch Weights for HMA Mixtures Containing RAP

Date: _____
Mix Type: _____

Prepared By: _____

[ ] - yellow cell denotes a required input.

% RAP Aggregate in Aggregate Blend (15% Maximum)	Asphalt Content of RAP (DWA)[1]

[1] DWA = Dry Weight of Aggregate

Table 1: Batch Weights for Virgin Aggregate, RAP and New Asphalt Binder

Parameter	Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Desired Total Asphalt Content of Mix, % (DWA)					
Desired Hot Mix Sample Weight, g					
Desired Weight of Aggregate, g	0.0	0.0	0.0	0.0	0.0
New Asphalt, % (DWA)	0.0	0.0	0.0	0.0	0.0
Weight of New Asphalt to be Added, g	0.0	0.0	0.0	0.0	0.0
RAP, % (DWA)	0.0	0.0	0.0	0.0	0.0
Weight of RAP to be Added, g	0.0	0.0	0.0	0.0	0.0
New Aggregate, %	100	100	100	100	100
Weight of Virgin Aggregate, g	0.0	0.0	0.0	0.0	0.0
Check	0.0	0.0	0.0	0.0	0.0

Table 2: Combined Gradation Summary

AGGREGATE:	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand		Blend[2]	Spec Limits
% of Blend w/ RAP	0.0														0.0	
% of Blend w/o RAP	0.0		0.0		0.0		0.0		0.0		0.0		0.0		0.0	
Sieve Size	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Desired % Passing	% of Blend (w/ RAP)	Total Blend (w/ RAP)	
1 1/2"		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
1"		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
3/4"		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
1/2"		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
3/8"		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 4		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 8		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 16		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 30		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 50		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 100		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	
No. 200		0.0		0.0		0.0		0.0		0.0		0.0		0.0	0.0	

[2] Must = 100%

Table 3: Input for Bin Batch Weights (from Table 1)[3]

Total Asphalt Content, %	
Desired Sample Wt., g	
Weight of RAP, g	
Weight of New Asphalt, g	
Wt. of Virgin Aggregate, g	

[3] When using RAP in HMA mix designs, the aggregate gradations and total asphalt content are altered slightly from original batch percentages due to the asphalt contained in the RAP. Therefore, the input data above must be entered separately for each total desired asphalt content to properly determine batch weights at each asphalt content.

Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
		0.0		0.0		0.0		0.0		0.0		0.0		0.0
1" - 3/4"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/4" - 1/2"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
1/2" - 3/8"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/8" - No. 4	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
No. 4 - PAN	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
	0.0	***0.0***	0.0	***0.0***	0.0	***0.0***	0.0	***0.0***	0.0	***0.0***	0.0	***0.0***	0.0	***0.0***

Cumulative Bin Batch Weights

Fraction	RAP		3/4"		1/2"		3/8"		Rock Dust		Natural Sand		Crushed Sand	
1" - 3/4"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/4" - 1/2"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
1/2" - 3/8"	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
3/8" - No. 4	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
No. 4 - PAN	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0	**0.0**
	0.0		0.0		0.0		0.0		0.0		0.0		0.0	

- yellow cell denotes a required input.